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The effect of environmental good scarcity on own-farm labor allocation: the case of agricultural households in rural Nepal*

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ABSTRACT As environmental goods such as fuelwood and fodder become more scarce, rural households in developing countries spend more time in their collection. It has been suggested that as a result households may reallocate labor away from own-farm agricultural production. This paper examines whether this is the case for a sample of agricultural households from rural Nepal. Cross-sectional estimates of agricultural labor demand equations give some indication that reallocation away from farm work may occur as environmental products become more scarce. However, these results disappear in random-effects estimation suggesting that time is instead reallocated from other activities or leisure. What little evidence there is for a labor reallocation from agriculture suggests that policies to relieve environmental good collection labor burdens should focus on leaf fodder and grass used as livestock feed rather than on fuelwood.

1. Introduction

There has long been considerable interest in the relationship between agriculture and the natural environment in developing countries. Much of the work exploring this relationship has tended to concentrate on natural resources as inputs to the agricultural production process. In one recent work, for example, Lopez (1997) tests and supports the hypothesis that natural biomass is an important factor of agricultural production in Ghana. In that case, biomass on fallow land provides soil nutrients and helps prevent erosion. In Nepal, the country of focus for this paper, studies of subsistence agricultural systems have emphasized the link between the use of forest products such as leaf fodder and agricultural production (see, e.g., Shroeder (1985), Bluffstone (1993, 1995), and Pradhan and Parks

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(1995)). Forest products become an input to agricultural production when they are fed to livestock which produce manure for fertilizer. This paper explores another possible link between forest products and agriculture. Natural resources, or more accurately their scarcity, may impact household-level agriculture by influencing the allocation of other factors of production, namely labor.

Rural households in developing countries typically rely heavily on self-collected environmental products such as fuelwood and leaf fodder to meet daily fuel and livestock feed requirements. When these products become more costly for households to collect due, for example, to the degradation of the natural environment, households spend more time in their collection. One possible result is the reallocation of labor time from other productive activities such as own-farm agricultural work to collection activities. This is thought particularly to be the case for women's time, since women are usually the primary collectors of environmental products.[1] However, there has been very little formal economic analysis of this link between the environment and agriculture despite its potentially serious consequences for subsistence level agriculturalists. Notable exceptions are Kumar and Hotchkiss (1988) and Bluffstone (1993, 1995).

Using household data from the middle hills of Nepal, this paper examines whether households that have higher costs of collecting environmental products devote less time to own-farm agricultural activities. This is a particularly pertinent question for the Nepal hills where agriculture is very labor intensive. Own-farm agriculture is the main source of food for hill households, and the caloric intake of the rural population in Nepal is generally low. These conditions emphasize the importance of understanding the factors which influence agricultural production in the region. Reductions in agricultural output stemming from less labor input are very likely to have detrimental health consequences.

In previous work with the same sample of Nepali households, Cooke (1998) shows that households allocate more time to collection activities when environmental products are more costly. As in this paper, household-specific shadow prices for the products measure the costliness of the products to a household and are assumed to increase with environmental degradation. The time spent collecting fuelwood, leaf fodder, and cut grass is found to increase significantly when household shadow prices for these products increased. For example, a shadow price increase of one rupee per 10 kilograms of fuelwood (about a 66 per cent increase) is found to increase household collection time by nearly one hour per day, mostly of women's time.[2] It is clear that this time must be reallocated from some other activity.

[1] Cecelski (1987); Kumar and Hotchkiss (1988); Cleaver (1992), Thapa, Bilsborrow, and Murphy (1995). See also Agarwal (1986); Dankelman and Davidson (1988); and Dasgupta (1993), chapter 10 for discussions of women and environmental good collection.

[2] Cooke (1998), table 2c. Although not included in Cooke (1998), an increase in the shadow price of water also significantly increases collection time, particularly that of women. The water shadow price is included in the present analysis along with those for fuelwood, cut grass, and leaf fodder.

The question addressed here is whether it comes at the expense of own-farm agricultural labor. Empirical evidence of such a labor allocation link between the natural resource base and agriculture would highlight the serious consequences of environmental degradation for subsistence level agriculturalists, and would perhaps increase the perceived benefits of policies to improve forest resources.

Analysis of this issue must take two important factors into account. One is the gender component of labor reallocation decisions. Women play an extremely important role in Nepali hill agriculture.[3] They also do most of the environmental good collection in Nepali households (see table 1), and according to Cooke (1998) they account for over 80 per cent of the increased collection time when environmental products become more costly. Therefore we would expect the allocation of female labor to agriculture to be more sensitive to environmental good scarcity than that of males. A second important factor is seasonality. It is shown in Cooke (1998) that the time allocated to collection activities varies significantly between seasons. This is also the case with time allocation to agriculture. Household shadow prices for self-collected environmental products will vary across seasons as well due to changes in product availability and collection conditions. Thus, using yearly cross-sectional results alone may obscure significant seasonal differences in labor allocation responses to higher environmental good shadow prices.

The Nepal Energy and Nutrition (NENS) data set used for the empirical analysis in this paper contains time allocation data which allow estimation of own-household agricultural labor demand equations for men and women.[4] It also contains four quarterly rounds of data collected over a one year period. To try to account for the impact of seasonality on household labor allocation decisions, labor demand equations are estimated not only with a cross-section of data aggregated to the yearly level, but also with the data set broken down into its four component quarters. Using the quarterly observations, cross-sectional demands are estimated separately for the monsoon and dry seasons. Finally, the demands are estimated using random-effects to take advantage of the panel aspects of the data.

Section 2 presents the theoretical framework for deriving household labor demand functions and shadow prices for environmental goods. Section 3 describes the data and the empirical strategy for estimation of the demand functions. Estimation results are discussed in section 4, and section 5 concludes.

2. Theoretical framework

The basis for the theoretical framework of this study is a neo-classical model of agricultural household production as described in Singh, Squire, and Strauss (1986). In the case presented here, markets for some of the

[3] See Shroeder (1985) for a detailed description of Nepali hill area agricultural systems.

[4] Nepal Energy and Nutrition Survey, 1982/1983, Western Region, Nepal. Nepal Agricultural Projects Service Center, the Food and Agriculture Organization of the United Nations, and the International Food Policy Research Institute.

goods in the model do not exist and the goods must be produced by the household.[5] The model begins with a representative household which is assumed to maximize its quasi-concave utility function myopically in each period. Here, each season is considered to be a separate period. To reduce clutter, time subscripts are suppressed for the discussion of the model. The utility function for each period may be written

$$U = U(X, M; D) \tag{1}$$

where M is the household's consumption of meals and X is its consumption of a vector of market goods. Household utility is assumed to be conditioned on a vector of fixed household characteristics, D, including size, ethnic background, and educational level which may affect preferences. The household purchases X at market price P_x, however meals are assumed only to be available from home production.

Households maximize their utility function subject to a set of production, budget, and time constraints. As with the utility function, these constraints are given for each period. The production constraint for meals is given by

$$M = M(T^{w}{}_{m}, E_{m}, GH) \tag{2}$$

and is concave in all its arguments. $T^{w}{}_{m}$ is the time household women spend in meal preparation, E_m, is a vector of environmental goods used as inputs to the meal production process, and GH is a vector of agricultural goods also used in producing meals. For example, E_m contains water and fuelwood which is used as cooking fuel, and GH contains household consumption of products such as rice and maize. Agricultural goods may be bought in the market place at price P_g or may be produced by the household. Environmental goods are assumed only to be available from home production (see below).

The household's concave agricultural production function is given by

$$G = G[T^{w}{}_{g}, T^{hw}{}_{g}, T^{m}{}_{g}, T^{hm}{}_{g}, N, K, E_{g}] \tag{3}$$

which is assumed to be concave and increasing in all its arguments. G is the production of crops which may be sold or consumed by the household. Agricultural labor used on a household's farm comes from own-household

[5] This household decision problem is described in Cooke (1998). This model also is similar to that presented in Bluffstone (1995). Bluffstone's work models the agriculture–forest relationship in rural Nepal and presents simulations that test for the effect of labor market conditions on the deforesting behavior of smallholder agricultural households. His household model incorporates household time devoted to fuelwood and fodder collection, agriculture, and off-farm wage labor. Bluffstone concentrates on the deforesting aspects of household labor allocation in his analysis, and abstracts to one six-month maize cultivation season for his simulations. This paper, particularly since it uses the same NENS data used by Bluffstone for his simulations, complements Bluffstone's work by focusing on agricultural labor, explicitly incorporating gender and seasonal factors, and relying on cross-sectional and panel data econometric estimation to glean further insights.

female labor, $T^{w}{}_{g}$, hired female labor, $T^{hw}{}_{g}$, own-household male labor, $T^{m}{}_{g}$, and hired male labor, $T^{hm}{}_{g}$. Production also depends on the amount of land a household has available to use, K, livestock holdings, N, and environmental goods that are inputs to the agricultural process, E_g. Landholdings are assumed to be exogenous in this model. Livestock holdings include male and female cattle and buffaloes and are also taken to be exogenous. Livestock contribute to agricultural production primarily by providing manure which is usually the only fertilizer used in the region. Additionally, some of the livestock are used as draught animals. E_g contains goods such as leaf fodder and cut grass which are fed to livestock, and thus contribute to fertilizer production.

The production functions for E_m and E_g are given by

$$E_m = E_m(T^{w}{}_{me}, T^{m}{}_{me}, A, D) \tag{4}$$

and

$$E_g = E_g(T^{w}{}_{ge}, T^{m}{}_{ge}, A, D) \tag{5}$$

These production functions differ only in the time variables for environmental good collection, subscripted 'me' and 'ge' for time devoted to meal-related environmental goods and agriculturally related environmental goods respectively. In this formulation both male and female time are spent in environmental good collection although they are not considered perfect substitutes. Both production functions are assumed to be linear functions of the time inputs implying constant marginal products for male and female labor for a given household in a given time period. The vector of household characteristics, D, and the state of the environment a household faces, A, will also influence the production of both types of environmental goods. For example, households comprised of elderly members may have lower marginal products as will households in locations where forest resources are more degraded. Since D and A will differ across households, marginal products of labor will differ across households as well.

The household time constraints are given in equations (6) and (7). Both men and women are assumed to have a fixed endowment of available work time given by T^m and T^w respectively. Women use this time for preparing meals, collecting environmental goods used in meal and agricultural production, own-farm agricultural labor, and wage labor (subscripted m, me, ge, g, and L respectively). Men are assumed to split their time between agricultural work on their own farm, collecting both types of environmental goods, and wage labor

$$T^w = T^{w}{}_{m} + T^{w}{}_{me} + T^{w}{}_{ge} + T^{w}{}_{g} + T^{w}{}_{L} \tag{6}$$

$$T^m = T^{m}{}_{g} + T^{m}{}_{me} + T^{m}{}_{ge} + T^{m}{}_{L} \tag{7}$$

Equation (4) gives the household's budget constraint. Household purchases of X at market price P_x are constrained by the amount of exogenous income Y a household receives, and its net earnings from selling agricultural products and labor. It is assumed that environmental goods are not bought and sold and are consequently only available from household production. This corresponds to the actual situation in the survey area during the early 1980s; there was very little trading of fuelwood and practically no trading of leaf fodder.[6] A household may buy and sell agricultural products at the price P_g. For the purposes of this model, agricultural products and other market goods X are assumed to be available in perfectly functioning competitive markets. It may also buy and/or sell male and female labor in competitive markets at wage rates W^m and W^w respectively. This assumption implies perfect substitutability between own-farm and hired male labor and between own-farm and hired female labor. It also implies that labor market opportunities are assumed to exist for both men and women. This is not an unreasonable assumption given the extent of the labor traded in the sampled villages. Although only about 25 per cent of the households in the sample used in this paper report women working for wages, almost all households hire female labor. Only one household in the sample appears to have no tie to the female labor market. About half of the sample households report men working for wages, and every household either hires or sells male labor

$$P_g(G-GH) + W^m(T^m{}_L - T^{hm}{}_g) + W^w(T^w{}_L - T^{hw}{}_g) + Y = P_xX \tag{8}$$

Substituting the production functions and time constraints into the budget constraint or into the utility function, the Lagrangian function for the household's maximization problem may be written

$$\begin{aligned}\text{Max } \mathscr{L} = {} & U\{X, M[T^w{}_m, E_m(T^w{}_{me}, T^m{}_{me}, A, D), GH]; D\} \\ & + \lambda\{P_g{}^*[G(T^w{}_g, T^{hw}{}_g, T^m{}_g, T^{hm}{}_g, K, N, E_g(T^w{}_{ge}, T^m{}_{ge}, A, D)) - GH] \\ & + W^{m*}(T^m - T^m{}_g - T^m{}_{me} - T^m{}_{ge} - T^{hm}{}_g) \\ & + W^{w*}(T^w - T^w{}_g - T^w{}_{ge} - T^w{}_m - T^w{}_{me} - T^{hw}{}_g) + Y - P_xX\}\end{aligned} \tag{9}$$

with the household choosing X, GH, and all time inputs. Assuming an interior solution, the first-order conditions may be derived and solved simultaneously for a set of reduced-form demand equations. One may also obtain derived demands for E_g and E_m. All demands will be functions of the exogenous variables (W^w, W^m, P_g, P_x, K, N, A, D, Y) and the shadow prices. The shadow prices themselves are functions of the exogenous variables and the quantity of the environmental product a household chooses to use (that quantity being determined here by the amount of time a household chooses to spend collecting the good).

The first-order conditions may be arranged to give

$$(W^w/E_{TWme})/P_g = (W^m/E_{TMme})/P_g = U_M M_{E\,m}/U_M M_{GH} \tag{10}$$

from which we may define the shadow price for meal-related environmental goods

$$\Pi_{E\,m} = (W^w/E_{TWme}) = (W^m/E_{TMme}) \tag{11}$$

The terms E_{TWme} and E_{TMme} are the marginal products of the time spent in

[6] Personal communications with Shubh Kumar of IFPRI (1996) and with Madhav Gautam, Nepal coordinator for the NENS survey (1997).

meal-related environmental good collection by women and men respectively. The shadow price $\Pi_{E\mathrm{m}}$ is defined as the women's wage rate divided by the marginal product of women's labor in the meal-related environmental good production or as the men's wage rate divided by the male marginal product of labor. Equation (10) simply gives the condition that a household will consume E_{m} and GH until the ratio of their 'prices' equals the ratio of the marginal utilities the household receives from an additional unit of them. Of course, $\Pi_{E\mathrm{m}}$ is not a market price, but a shadow price that is determined endogenously by the household's choices. Specifically, it will depend on household preferences over meals. Since these preferences will vary from household to household, so will this shadow price.[7]

The first-order conditions also yield the similarly defined shadow price for environmental goods used in agriculture

$$\Pi_{\mathrm{Eg}} = (W^{\mathrm{w}} / E_{\mathrm{TWge}}) = (W^{\mathrm{m}} / E_{\mathrm{TMge}}) = G_{E\mathrm{g}} P_{\mathrm{g}} \tag{12}$$

Here, E_{TWge} (E_{TMge}) is the marginal product of women's (men's) labor in agricultural-type environmental good production and $G_{E\mathrm{g}}$ is the marginal product of E_{g} in agricultural production. This shadow price, $\Pi_{E\mathrm{g}}$, will depend on a household's agricultural technology as well as household preferences, and a household will equate this shadow price to the value of the marginal product of E_{g}.

Shadow prices are assumed to reflect the relative economic cost of environmental products to a household. Controlling for endogenous productivity factors, this cost is largely determined by the environmental conditions a household faces. These conditions include distance to the source, steepness of terrain, and the level of environmental degradation. A household living in relatively worse environmental conditions (e.g., more degraded) will have to spend more time to collect a unit of the product than will a household living in better environmental conditions. Hence, households in worse environmental areas will tend to have higher shadow prices. Obviously, shadow prices are also influenced by a household's wage rates. However, as is discussed more in the data section, wage rates do not vary a great deal across the sample considered in this paper, and so their influence in this case is minimal.

Shadow prices will vary between seasons. In the model presented here agricultural and environmental good production functions are written identically for each period. Obviously, production conditions and thus a household's productivity are likely to change over the course of a year. It is much harder to produce fuelwood in the heavy monsoon season, for example. Therefore the production functions in (3), (4), and (5) are assumed to shift over seasons. This does not change the general interpretation of the first-order conditions. However, a given household will have differing values for its marginal products of labor at different times of the year and, consequently, it's shadow prices will vary as well. Shadow prices for the NENS households do in fact show seasonal variation as is discussed more in the data section.

[7] See Singh, Squire, and Strauss (1986) for more on shadow prices in agricultural household models

3. Data and empirical strategy

The data set used for this study is from the Nepal Energy and Nutrition Survey, 1982/1983 (NENS) and contains four quarterly rounds collected over a one-year period. The data as received by the author were at the household level, no individual level data were reported. There are data for 118 households sampled from three village *panchayats* in three different districts in the Western Development Region of Nepal's middle hills. *Panchayats* are local government units below the district level. Each *panchayat* contains several wards which correspond closely to villages. Approximately 20 households were randomly sampled from each of two wards selected from each of the three sample *panchayats*. First *panchayats* and then wards were chosen to obtain variation in market access, ethnicity, altitude, and environmental degradation.[8]

The survey region consists of hills and valleys with the study households living between roughly 500 and 1500 meters. Ethnically, the sample is comprised mostly of Hindu households of the Brahmin (high) caste, although there are many Tibeto-Burman households as well. Brahmin households have higher income and consumption per capita than other sample households, and they tend to own more livestock due to religious prescriptions. All sample households collect and use environmental products, and all of the households are agricultural. They all own at least some land with a sample average of slightly less than 1½ hectares per household. This includes both upland area (*pakho*) found on hillsides, and lowland area (*khet*) which is usually found in valley bottoms. Lowland may be irrigated. Sample households mainly grow wheat, rice, maize, and ragi (finger millet), and most of them rely heavily on their own farm's production for their food consumption.

Collecting environmental products, engaging in own-farm agricultural activities, and preparing food for consumption comprise a very large proportion of a household's available work time. Households collect fuelwood, leaf fodder, cut grass, and water. Over the course of a year households spend an average of almost eight hours per day collecting these four environmental products, around ten hours per day in own-farm agricultural labor, and over five hours per day in food preparation. Women's labor accounts for most of the time spent collecting environmental products and preparing food, and slightly less than half of the agricultural labor time. On average each adult woman in a household spends about nine hours per day and each adult man spends slightly less than five hours per day doing these three activities.

These yearly averages hide significant fluctuations in labor allocation over different seasons. Table 1 presents data for household time allocation for men, women, and youths age 6–15 by season for the year covered by the Nepal Energy and Nutrition Survey. In this table own-farm agricultural labor has been converted to hours per day from the eight-hour labor day units reported in the NENS data. In the survey villages the monsoon season runs from April to September with the July–September quarter

[8] See Kumar and Hotchkiss (1988) for more information on the survey design and sampling strategy.

seeing the heaviest rains. The period from October through March is the dry season. It may be noted that farm labor time and collection time both vary considerably between seasons, although food preparation and cooking time does not vary that much. Food preparation includes activities such as milling, while cooking is the time spent preparing meals. Both men and women spend more time collecting environmental products during the monsoon season. This is largely attributable to spending more time cutting grass which is only available at this time of year. Youths also spend more time collecting during the monsoon, although the total times reported here are rather small in comparison to the adult times. Youths are usually responsible for grazing herd animals, and grazing time is not included in this table.

Households use the four environmental goods considered in this study mostly for fuel and for feeding livestock. Fuelwood is the primary cooking fuel and is used both for family meal preparation and for cooking *kundo*, a cooked gruel of oilseed cake, straw, and water which is fed to livestock. The NENS data do not report how much fuelwood and water households use for *kundo* preparation. None of the households use improved wood-burning or commercial fuel stoves, found by Amacher, Hyde and Joshee (1993) to be technological substitutes for fuelwood use, nor do they use dung as fuel. Rural Nepali households often stall feed their livestock leaf fodder and cut grass. Cut grass is considered a superior feed and is relied on quite heavily during the rainy season. During the dry season when grass is not available, households feed their animals more leaf fodder and straw, and spend more time grazing them. The uses to which collected water is put are not specified in the NENS data.

The model presented in the previous section implies a system of simultaneously derived household demand equations that are functions of all exogenous variables and of the endogenous shadow prices. Although the whole system of demand equations has been estimated, this paper reports only a subset. Cooke (1998) shows that households spend more time collecting environmental goods when their shadow prices increase. Of particular interest here is whether this is achieved by reallocating labor away from agricultural production activities. Since the focus of this paper is on household labor allocation to own-farm agriculture, only the results for labor input demands to own-farm agricultural work are presented.

Cross-sectional demands with data aggregated to the yearly level are estimated with two stage least squares (2SLS) to control for the endogeneity of the shadow prices. Also, cross-sectional demands using 2SLS are estimated for the rainy and dry seasons separately. In this case, each season is assigned the two quarterly rounds of data which coincide with the correct time of year, and a dummy variable is included for one of the quarters. For many of the demands a Hausman specification test (Hausman, 1978) could not reject the null hypothesis of exogeneity of one or more shadow prices. If the exogeneity of all shadow prices could not be rejected, then OLS results corrected for heteroskedasticity are presented.

The quarterly observations of the NENS data allow the demand equations to be estimated using panel data techniques as well as cross-sectional ones. Using panel techniques, equations are estimated for the panel con-

Table 1 *Household time allocation by season (in hours/hh/day)*

	April–June			*July–September*			*October–December*			*January–March*		
Activity	*Men*	*Women*	*Youths*	*Men*	*Women*	*Youths*	*Men*	*Women*	*Youths*	*Men*	*Women*	*Youths*
Own-household farm labor	3.3 (4.2)	3.1 (4.0)	0.002 (0.02)	6.8 (9.8)	6.0 (7.0)	0.002 (0.02)	6.7 (9.4)	5.7 (6.5)	0.02 (0.1)	3.8 (4.6)	3.6 (4.2)	0.02 (0.1)
Environmental good collection	3.3 (2.4)	8.2 (4.4)	1.4 (1.2)	0.3 (1.1)	7.1 (3.8)	2.1 (2.0)	0.8 (1.5)	4.3 (3.7)	0.6 (1.7)	0.5 (0.8)	4.9 (4.2)	0.2 (0.4)
Food preparation and cooking	0.9 (0.7)	5.1 (2.1)		0.9 (0.9)	5.0 (1.4)		0.8 (0.6)	4.6 (1.3)		0.8 (0.6)	4.0 (1.4)	
Household production total	7.5 (5.1)	16.4 (7.6)	1.4 (1.2)	8.1 (9.9)	18.2 (8.8)	2.1 (2.0)	8.4 (9.6)	14.6 (9.1)	0.6 (1.7)	5.2 (4.8)	12.5 (7.6)	0.2 (0.4)
Wage labor*	3.8 (13.8)	4.2 (16.3)		9.2 (27.9)	3.6 (14.8)		8.0 (21.9)	.3 (1.8)		25.3 (43.8)	1.2 (8.3)	

Notes: Standard deviations in parentheses.
*Days per quarter
Source: Nepal Energy and Nutrition Survey, 1982/83.

Table 2 *Household labor to own-farm agriculture*

Variable	*Units*	*Mean*	*Std.Dev*
Total farm labor time	man-days/year	444.6	452.0
Women's farm labor time	man-days/year	208.1	211.2
Men's farm labor time	man-days/year	234.8	270.0
Total farm labor time	man-days/quarter*	111.3	141.9
Women's farm labor time	man-days/quarter*	52.2	65.2
Men's farm labor time	man-days/quarter*	58.7	86.7

Notes: *Average over all four quarters.
Source: Nepal Energy and Nutrition Survey, 1982/83.

taining all four quarters, and for the rainy and dry seasons separately. Panel data estimation techniques are used to control for omitted variable bias due to the exclusion of unobserved household level factors that are correlated with the error terms of the estimated demand equations. This should control for household productivity differences not already captured by the household composition variables. As discussed in Hsiao (1986), the unobserved, household-specific effects may be modeled either as being fixed or as occurring randomly in the sample population. For this study, both fixed-effects and random-effects models are estimated and a Hausman specification test is used to determine the correct specification. The random-effects specification cannot be rejected, and so only the random-effects results are presented in this paper.

Table 2 summarizes the dependent variables. The NENS data set provides the number of days of household male and household female labor spent on seven principal crops farmed by households in the survey region. This labor allocation data were collected by crop, not by quarter, and in some cases a crop's growing season spans two of the survey quarters. To convert the crop-specific labor allocation data into quarterly figures the time for each crop is assigned to the quarter which most accurately reflects its growing season. The cropping calendar which was the basis for this assignment is given in Kumar and Hotchkiss (1988, p. 21). In cases where the growing season for a crop is relatively evenly split between two quarters, the labor days for that crop are also split and assigned evenly between those quarters.[9] As seen in table 2, household labor allocation to agriculture varies substantially across households as evidenced by high standard deviations relative to the mean for both male and female labor. Additionally, the standard deviation for male labor is high compared to the mean labor supplied suggesting that many households have a very high male labor input to own-farm agriculture.

The regressors corresponding to the exogenous and shadow price vari-

[9] Combining the data into two periods, for the wet season and for the dry season, avoids splitting labor days between periods in this fashion. The labor demand equations were estimated with this two season model for comparison. Labor days for maize and early paddy were dropped since their growing periods both start in the dry season and end in the rainy season. Estimation results from the two season model are very similar to those presented in this paper.

Table 3 *Explanatory variables (yearly averages)*

Variable	*Definition*	*Mean*	*Std. Dev.*
Fuelwood shadow price	Rs/10 kgs	1.53	1.02
Water shadow price	Rs/10 trips	0.28	0.23
Grass shadow price	Rs/10 kgs	0.66	0.78
Fodder shadow price	Rs/10 kgs	0.63	0.91
Female wage rate	imputed average daily wage rate for household females	5.15	0.77
Male wage rate	imputed average daily wage rate for household males	11.19	3.04
Male adults	number of household males age 16–59	1.68	1.03
Female adults	number of household females age 16–59	1.70	0.96
Youths	number of household children ages 6–15	1.64	1.30
Children	number of household children under age 6	1.34	1.13
Adult literacy	percentage of literate household adults	42.28	28.84
Upland area	hectares of upland area owned by the household	0.83	0.72
Lowland area	hectares of lowland area owned by the household	0.62	0.57
Bovine	number of cattle and buffaloes	5.58	4.01
Caste dummy	Dummy = 1 if household is Tibeto-Burman and 0 otherwise	0.33	0.47
Location dummy	Dummy = 1 if in Chhoprak *panchayat* and 0 otherwise	0.32	0.47
Altitude	meters	887.23	295.09
Remittances	total amount of remittances to the household, in rupees	1401.42	3127.77
Round 1	Dummy = 1 if April–June (early monsoon)		
Round 2*	Dummy = 1 if July–September (heavy monsoon)		
Round 3	Dummy = 1 if October–December (dry season)		
Round 4	Dummy = 1 if January–March (dry season)		

Note: *The dummy variable for round 2 is dropped for estimation purposes in the full panel of data.
Source: Nepal Energy and Nutrition Survey, 1982/83.

ables in the theoretical model are described in table 3. As discussed earlier, not all households have men or women who report working for wages. Thus, household-level average daily wage rates for men and women in households that do have such data are used to impute average daily wage rates for the entire sample. These wages are imputed using a Heckman procedure to control for any selection bias.[10] Shadow prices are then computed using the imputed women's wage rates from the Heckman estimation. This is done by multiplying the imputed women's wage rate for a household (converted to rupees/hour) by the average time it takes the household to collect 10 kilograms of the environmental product (which corresponds to the inverse of the constant marginal product of labor).[11] Imputed wage rates, collection times, and shadow prices are all household specific. The formulation of the shadow prices using the imputed female wage rate was chosen over a formulation using the imputed male wage rate since women account for over 70 per cent of total household time spent collecting the four environmental products considered in this paper.

Shadow prices measure the economic scarcity of environmental goods to a household, and, correcting for household-level productivity differences, may be taken to reflect environmental conditions. As noted before, environmental conditions comprise a variety of factors including distance to the forest, steepness of terrain, and seasonal conditions as well as level of forest degradation. All of these factors vary across the households in the NENS sample. Additionally, it should be noted that although some environmental conditions and the shadow prices do vary quite a bit over seasons, the one year of data in the NENS sample is not enough to assess dynamic responses to environmental degradation which occurs over a much longer period.

It is also worth noting that relative wage rates will also influence a household's shadow prices. Households with a high opportunity cost for their time spent collecting will face higher shadow prices, everything else held constant. Thus, the economic cost to a household of collecting a unit of an environmental product is determined both by factors which influence collection productivity, and by the opportunity cost of the time spent collecting as given by the wage rate. For this sample, the standard deviation of the female imputed daily wage rate is relatively small and that of the shadow prices relatively large, implying that much of the variation in shadow prices across the sample comes from variation in per unit collection times. All equations in this paper have also been estimated using

[10] Heckman (1979). The null hypothesis of no selection bias could not be rejected in either model. The econometric specification used is given in Cooke (1998), appendix A.

[11] Daily wage rates are converted to rupees/hour by assuming an eight-hour work day. The choice of making the shadow prices rupees per 10 kilograms verses per 1 kilogram or 100 kilograms is arbitrary. It should be noted that a 1 rupee price increase for any of the environmental goods considered is very large in percentage terms. The data give the time per trip to collect water, not the time per water unit, so the shadow price for water is given by rupees per ten trips. This may still function as a reasonable shadow price given the assumption that households collect the same amount of water on each trip.

simply the time to collect 10 kilograms of a good (or time per trip in the case of water) instead of the full shadow prices. The results are very similar to those presented here.[12]

The amount of lowland area (*khet*) and upland area (*pakho*) a household owns correspond to the variable K in the theoretical model. Altitude may also account for differences in farming conditions. The number of cattle and buffaloes a household owns measures livestock holdings N. Male bovines are used as draught animals and females provide manure which is used as fertilizer. Both male and female bovines are fed using environmental products such as leaf fodder. Remittances are included as a measure of a household's non-wage exogenous income Y. The household adult literacy rate, caste, and household composition variables belong to the household characteristic vector D. The dummy variable for Chhoprak *panchayat* serves as a rough proxy for the state of the environment variable, A. Kumar and Hotchkiss (1988) report that this *panchayat* is in a much more deforested area than the other survey sites. Of course, using this location dummy will capture other *panchayat*-level characteristics as well. Unfortunately, there is no exogenous measure of environmental conditions in the NENS data which could otherwise be used.

Not every variable from the theoretical model can be included in the empirical estimation due to data limitations. For one, the prices of agricultural goods do not vary across the sample. The prices of other market goods also are not included since they either are unavailable or do not vary across the sample. Additionally, not all of the variables used in the yearly cross-sectional regressions may be used in the regressions using quarterly observations. Quarterly imputed wages are almost perfectly collinear with the seasonal dummies and so are omitted. Remittances are not included since there are no observations for the April–June quarter**.** A joint F-test for the exclusion of the wage and remittance variables from the yearly cross-sectional equations cannot reject (at the 5 per cent level) that they may be dropped from the total own-farm labor and male own-farm labor equations. However, the F-test does reject dropping them from the female own-farm labor equation at the 5 per cent level, although not at the 1 per

[12] The coefficients on the time per unit measures of environmental good scarcity have the same sign, significance level, and order of magnitude as the coefficients on the shadow prices. The exception to this is the coefficient for the 'price' of leaf fodder in the dry season cross-sectional equations. The time per unit measure is more significant in the total farm labor and male farm labor equations than the shadow price coefficient (significant at the 5 per cent level as compared to the 10 per cent level). This difference does not hold in the random-effects estimates. Given that there are not complete wage data and that the wages themselves show little variation, it has been suggested that the results of the time per unit estimation be reported in this paper instead of the shadow price results. This would emphasize the variation in household costs due to environmental conditions. However, in order to more clearly maintain the link between the theoretical and empirical models I have chosen to present the shadow price estimates. The full economic cost of environmental goods to a household influences household decisions. In the case here, factors which affect household productivity such as environmental conditions are the main cause of variation in the economic cost.

cent level. This indicates that comparisons of the cross-sectional results including the variables with subsequent female labor equations should be treated with a bit of caution.

Some variables are dropped in moving from cross-sectional to panel estimation due to the nature of environmental good collection in the Nepal Hills. In the random-effects model which covers all four quarters shadow prices for leaf fodder and grass are excluded, since there are almost no observations for them in the rainy and dry season quarters respectively. This is due to the extreme seasonality of the use of these two types of feed; in general, grass is not used in the dry season and leaf fodder is not used in the rainy season. In the cross-sectional regressions, the shadow price of cut grass is included in the rainy season equations, and the fodder shadow price is included in the dry season equations. In the separate rainy and dry season random-effects equations (each with two quarters) the shadow prices are handled in similar fashion.

4. Empirical results

Table 4 indicates how the demand for own-household agricultural labor is related to the shadow prices of fuelwood, water, cut grass, and leaf fodder. The results are for labor demand equations estimated first using 2SLS on cross-sectional data and then random-effects on panel data. Only the coefficients on the shadow prices of the environmental goods are included in table 4 since they are the main focus of this study. Full estimation results may be found in the appendix.

The shadow price coefficients from cross-sectional estimation are presented in Table 4 under the columns ‘Yearly’, ‘Rainy’, and ‘Dry’. The ‘Yearly’ columns contain results for equations estimated with data aggregated to the yearly level. The ‘Rainy’ and ‘Dry’ columns contain cross-sectional estimates from equations using quarterly data for the rainy and dry quarters respectively. The cut grass (leaf fodder) shadow price is not included in the dry (rainy) season estimations, since it is not observable for most households during this season.

The fourth column under each shadow price is labeled RE for random-effects. Random-effects equations are estimated three different ways. In one way all four quarters of data are used. The shadow prices of water and fuelwood are included since they are used consistently throughout the year and there are observations on these variables for all four quarters. These are the results presented under the water and fuelwood price columns. The random-effects models for the rainy and dry seasons are also estimated separately using the quarters of data corresponding to each season. These models include the cut grass or the leaf fodder shadow price, whichever is appropriate for the season, as well as the shadow prices for water and fuelwood. The random-effect coefficient estimates for the shadow price of cut grass (rainy season) are presented in the grass price RE column, and those for the shadow price of leaf fodder (dry season) are shown in the fodder price RE column. Full results for all three random-effects models are included in the appendix.

By estimating the three agricultural labor demand equations first using cross-sectional data techniques and then using panel techniques, we may

Table 4 *Shadow price coefficients for household agricultural labor input demands (days per year or per quarter)*

	Fuelwood price				*Water price*				*Grass price*				*Fodder price*			
	Yearly	*Rainy*	*Dry*	*RE*[1]	*Yearly*	*Rainy*	*Dry*	*RE*[1]	*Yearly*	*Rainy*	*Dry*	*RE*[2]	*Yearly*	*Rainy*	*Dry*	*RE*[3]
Male	−34.6	−0.6	1.7	−0.1	**36.7**	**4.8**	**8.0**	**4.3**	−1.2	−7.7	—	−7.7	−**41.4**	—	−*11.0*	−11.0
	(1.6)	(0.5)	(0.4)	(0.07)	**(3.3)**	**(2.1)**	**(2.4)**	**(3.6)**	(0.1)	(0.9)		(0.6)	**(2.2)**		*(1.7)*	(1.0)
Female	−6.6	−0.7	0.9	0.2	9.0	1.8	**4.1**	**1.9**	−2.5	−*12.8*	—	−*12.8*	−20.4	—	−4.4	−4.4
	(0.4)	(0.7)	(0.4)	(0.2)	(1.6)	(1.3)	**(2.7)**	**(2.3)**	(0.3)	*(1.8)*		*(1.68)*	(1.4)		(0.9)	(0.6)
Total	−41.2	−1.4	2.1	−0.1	**45.8**	**6.6**	**12.2**	**6.5**	−3.7	−20.8	—	−20.8	−**61.9**	—	−*15.5*	−15.5
	(1.3)	(0.7)	(0.5)	(0.06)	**(3.4)**	**(2.1)**	**(2.9)**	**(3.6)**	(0.2)	(1.5)		(1.2)	**(2.2)**		*(1.65)*	(0.9)

Notes: Absolute *t*-statistics or *z*-statistics in parentheses. Estimates significant at the 10 per cent level in italics, at the 5 per cent level or better in bold.
(1) Random-effects using all four quarters. (2) Random-effects using rainy season quarters only. (3) Random-effects using dry season quarters only.

examine whether cross-sectional estimation results persist after correcting for unobservable household effects. In Cooke (1998) higher shadow prices were shown to significantly increase collection time using both cross-sectional and panel data econometric models. If there is a time reallocation away from agricultural labor as a result of increased collection time, then it should be discernible in the random-effects estimates as well as in cross-sectional ones. However, it appears from all of the results presented in table 4 that there is relatively little labor reallocation away from agriculture. There is almost no significant reduction in own-household agricultural labor evident from the random-effects estimates, and very little in the cross-sectional estimates.

The strongest negative result on any of the shadow prices is for the fodder shadow price. The yearly cross-sectional results indicate that a higher fodder shadow price significantly reduces male farm labor input. However, fodder is collected primarily in the dry season, and these results are much weaker in the dry season cross-sectional estimates and disappear in the dry season random-effects estimates. The shadow price for cut grass is significantly negative at the 10 per cent level in the rainy season women's labor equation. This result, albeit a weak one, persists in the random-effects specification. Cut grass is only available during the monsoon season, and during that time women spend an average of four hours per day collecting it to stall feed livestock. Men collect grass in the early monsoon season, but women account for most of the collection time in the later monsoon season when agricultural labor requirements are high. Thus, it is not surprising that this result is only significant for the women's labor equations.

Interestingly, the shadow price coefficients for fuelwood are not significant in any of the regressions, although they are mostly negative. It appears that the scarcity of environmental goods that are important seasonal livestock feeds have more of a negative impact on household farm labor allocation than does scarcity of fuelwood. This is not terribly surprising when one considers the nature of collection of these goods. Fuelwood is not collected everyday. It is possible to store fuelwood and, therefore, it is possible to coordinate fuelwood collection times with slacker agricultural times. Leaf fodder and cut grass, on the other hand, are not stored, but are collected and fed to livestock on more of a daily basis. One would thus expect a stronger effect on agricultural labor allocation from the fodder and grass shadow prices than from the fuelwood shadow price.

Perhaps the most striking results in table 4 are the coefficient estimates on the water shadow price. Unlike the other three shadow prices, an increase in the shadow price of water is associated with a significantly higher labor allocation to agriculture. It is very difficult to explain this result, particularly as it is robust to all of the econometric specifications. The result indicates that there is some substitution of time *into* agricultural labor when water is more costly. Although the NENS data do not specify the specific uses to which collected water is put, it is not for irrigation purposes making this all the more puzzling. Possibly this result is picking up spatial aspects of household, agricultural field, and water source locations.

This explanation is less convincing given that the water shadow price coefficients are significantly positive in both random-effects and fixed-effects estimates as well as cross-sectional ones. It is possible that the shadow price variable is misspecified. It should be noted that the shadow price of water is calculated using the 'time per trip' as opposed to a time per unit of water collected. This may be an inferior measure which is introducing some error into the estimation.

In addition to the environmental good shadow price coefficients in table 4, there are other results in the appendix tables that deserve discussion here. The factors exerting the strongest influence on the amount of time men and women spend in agricultural labor appear to be the amount of land a household owns and the time of year. Neither of these are terribly surprising, but they bear closer inspection. The number of children in a household also turns out to be quite influential.

The amount of land a household owns significantly increases the time men and women spend in agricultural labor. More interestingly, it appears that upland area and lowland area influence labor allocation differently. Owning more upland area significantly increases both male and female labor input in all cross-sectional specifications, but female labor input increases by a larger amount. Owning more lowland area only significantly increases male labor input. A partial explanation for this latter result is that most households in the sample irrigate their lowland area and maintaining water flow tends to be a male task. A more direct explanation for both upland and lowland coefficients is that on average men spend much more time in padi production than women do (165 days/year for men versus 95 days/year for women) and that women spend much more time in ragi (finger millet) production than men (153 days/year for women versus 111 days/year for men). Padi is a lowland crop and ragi is an upland crop. The gender division of labor between these two crops probably accounts for the difference in male and female upland and lowland coefficient estimates since men and women spend roughly the same amount of time on the other crops.

Seasonality also has an extremely strong effect on agricultural labor allocation. This is quite clear from the significance of included seasonal dummy variables in both cross-sectional and random-effects models. Most agricultural activity occurs during the height of the monsoon season and the quarter after it. In the random-effects model with all four quarters, male and female labor times are both significantly lower in the first and fourth rounds (April–June and January–March) compared to the omitted, heavy monsoon second round (July–September). In the rainy season cross-sectional and random-effects models, the heavy monsoon seasonal dummy is significantly positive compared to the early monsoon period for all equations. The same is true of the early dry season dummy compared to the late dry season period in all dry season models.

Finally, the number of young children in a household has a negative and significant coefficient in almost all of the equations. Having an additional small child tends to reduce the amount of time both men and women spend in agricultural activities. This result is quite strong in the rainy season random-effects model, and all but disappears in the dry season random-effects model. The monsoon season is a period of intense agricultural activity. Labor constraints are likely to be tighter in this season, so having to look after a small child is more likely to cut into agricultural time. There may also be weather-related factors that make joint production of child raising and agriculture less feasible in the monsoon season.

5. Conclusion

The relationship between rural agricultural households and the environment is a very close one in many developing countries. This paper has examined one avenue by which scarcity of environmental resources can influence household level agriculture in rural Nepal. Overall, the results of this study give little clear support to the claim that households, and women in particular, will spend less time farming when it becomes more costly to collect environmental products such as fuelwood. Very few shadow price coefficients are significantly negative in either the cross-sectional or the random-effects labor demand equations. In fact, an increase in the shadow price of water appears to actually increase a household's agricultural labor allocation. It appears that seasonal factors, household landholdings, household composition, and traditional gender roles in agriculture exert more influence on household agricultural labor allocation decisions than does an increase in the cost of collecting environmental products.

Despite the lack of strong empirical evidence in the NENS data supporting labor reductions to agriculture when faced with higher shadow prices, it still remains that these households do reallocate their time when environmental goods are more costly. Households in this sample spend significantly more time collecting environmental products when shadow prices are higher, and most of this time increase comes from women.[13] The results in this paper imply that most of the reallocated time must come from another productive activity or from leisure. It is quite conceivable that agriculture is such a high priority for these subsistence farmers that sacrifices will be made in leisure or other less crucial activities before agricultural labor time is reduced. Given this explanation, the fact that there is any evidence at all of labor reallocation away from agriculture indicates that the environmental goods are extremely important and have become costly enough to significantly tighten household labor constraints.

An alternative, or complementary, explanation for the findings in this paper is that the timing of agricultural and collection activities may be such that agricultural labor reductions are not necessary. For example, fuelwood is not collected every day. Indeed, it may be collected and stored for some time before it is used. It is quite possible for households to do the bulk of their fuelwood collection in the dry season which is an agriculturally less intense time of year (although households do collect some fuelwood in the monsoon season). This line of reasoning also helps explain why the shadow prices of grass and fodder tend to be more significant than that of fuelwood; fodder and grass are collected on more of a daily basis and are not stored. Although fuelwood is a vitally important good for

[13] Cooke (1995, 1998).

rural Nepalis, this analysis indicates that the tightening of labor constraints imposed by higher collection costs of leaf fodder and grass for livestock feed may pose more of a problem for rural households. This would suggest that policies geared toward relieving the burden of collection activities for rural households, and for women in particular, should focus more on livestock feed issues than on fuelwood.

It should be noted that this paper does not claim that scarcity of environmental goods will never lead households to reallocate time away from agriculture, although it does seem clear that this would not be the first response. In areas where environmental degradation is much more serious than in the NENS villages such reallocation away from agriculture may occur, particularly if there are few feasible substitutes for self-collected environmental goods. Soussan *et al.* (1991), for example, describe villages in the Dhanusha District of Nepal where women must make one or two day trips to collect fuelwood because the forest has become increasingly distant and degraded. It would seem that this level of scarcity would have a stronger effect on household labor allocation decisions.

Still, one should realize that reallocating labor is only one method households have of dealing with environmental good scarcity, and it is likely to be a short-run solution at best. If environmental goods continue to become more and more costly to collect, at some point households will turn to other methods of coping such as planting trees on their property. Some households in the NENS sample have, in fact, begun planting fodder trees. However, incentives to pursue this strategy may be limited if the trees compete with agricultural crops. Understanding the conditions under which rural households will pursue different coping strategies for environmental good scarcity, and the impact of these strategies on agricultural decisions, are important avenues for future research.

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Appendix

Yearly cross-sectional demands for household agricultural labor (days/year)

	Male	*Female*	*Total*
Fuelwood shadow price	−34.6	−6.6	−41.2
	(1.6)	(0.4)	(1.3)
Water shadow price	**36.7****	9.0	**45.8****
	(3.3)	(1.6)	**(3.4)**
Cut grass shadow price	−1.2	−2.5	−3.7
	(0.1)	(0.3)	(0.2)
Leaf fodder shadow price	**−41.4****	−20.4	**−61.9****
	(2.2)	(1.4)	**(2.2)**
Female daily wage rate	33.8	−24.55	8.2
	(0.8)	(0.9)	(0.1)
Male daily wage rate	**97.0****	−25.1	71.2
	(2.0)	(1.0)	(1.2)
Location dummy = 1 if Chhoprak	**140.2****	−60.0	80.4
	(2.4)	(−1.5)	(1.0)
Caste dummy = 1 if Tibeto/Burman	−104.7	−48.2	−153.8*
	(1.4)	(1.4)	(1.8)
Upland area	**200.1****	**228.2****	**428.3****
	(8.7)	**(6.6)**	**(8.5)**
Lowland area	**119.9****	14.6	134.1
	(2.0)	(0.4)	(1.6)
Bovine livestock	−10.4	−0.3	−10.8
	(1.4)	(0.07)	(0.9)
Altitude	0.1	0.1	0.2
	(1.1)	(1.4)	(1.5)
Percentage of literate adults	−8.36*	3.4	−4.8
	(1.8)	(1.4)	(0.8)
Male adults	32.6	−4.1	29.7
	(1.1)	(0.3)	(0.9)
Female adults	21.9	**29.7****	51.3
	(1.5)	**(2.1)**	(2.0)
Youths age 6–15	17.2*	14.1*	31.5*
	(1.7)	(1.7)	(1.9)
Children under age 6	**−52.2****	**−33.0****	**−85.5****
	(3.5)	**(2.4)**	**(3.5)**
Annual remittances	0.003	**0.01****	**0.01****
	(0.7)	**(3.2)**	**(2.0)**
Constant	−1064.2*	178.5	−877.1
	(1.8)	(0.6)	(1.2)
Number of observations	102	102	102
Adjusted R-square	0.66	0.72	0.75

Notes: *significant at the 10 per cent level, **significant at the 5 per cent level (also in bold type).
Absolute *t*-statistics in parentheses.

Rainy season cross-sectional demands for household agricultural labor (days/quarter)

	Male	*Female*	*Total*
Fuelwood shadow price	−0.6	-0.7	−1.4
	(0.5)	(0.7)	(0.7)
Water shadow price	**4.8****	1.8	**6.6****
	(2.1)	(1.3)	**(2.1)**
Cut grass shadow price	−7.7	−12.8*	−20.8
	(0.9)	(1.8)	(1.5)
Location dummy = 1 if Chhoprak	−0.94	1.6	0.6
	(0.1)	(0.1)	(0.04)
Caste dummy = 1 if Tibeto/Burman	13.4	−22.4*	−36.3
	(0.8)	(1.7)	(1.5)
Upland area	**49.3****	**54.7****	**104.2****
	(4.9)	**(5.8)**	**(6.1)**
Lowland Area	31.3	−10.1	21.0
	(1.6)	(1.0)	(0.8)
Bovine livestock	0.1	1.7	1.9
	(0.07)	(1.4)	(0.5)
Altitude	−0.009	**0.04****	0.03
	(0.4)	**(2.0)**	(0.9)
Percentage of literate adults	0.1	**0.2****	0.4*
	(0.8)	**(2.5)**	(1.8)
Male adults	6.3	1.0	7.3
	(0.6)	(0.2)	(0.5)
Female adults	3.8	4.2*	8.0
	(0.9)	(1.1)	(1.1)
Youths age 6–15	2.0	5.0	7.1
	(0.9)	(1.5)	(1.6)
Children under age 6	**−9.9****	−6.3*	**−16.3****
	(3.2)	(1.7)	**(2.7)**
Seasonal dummy = 1 if July–September	**41.4****	**31.8****	**73.5****
	(3.7)	**(4.8)**	**(4.8)**
Constant	−35.2	**−61.2****	**−96.4****
	(1.3)	**(4.8)**	**(2.3)**
Number of observations	213	215	213
Adjusted R-square	0.40	0.52	0.51

Notes: *significant at the 10 per cent level, **significant at the 5 per cent level (also in bold type).
Absolute *t*-statistics in parentheses.

Dry season cross-sectional demands for household agricultural labor (days/quarter)

	Male	*Female*	*Total*
Fuelwood shadow price	1.7	0.9	2.1
	(0.4)	(0.4)	(0.5)
Water shadow price	**8.0****	**4.1****	**12.2****
	(2.4)	**(2.7)**	**(2.9)**
Leaf fodder shadow price	−11.0*	−4.4	−15.5*
	(1.7)	(0.9)	(1.65)
Location dummy = 1 if Chhoprak	−15.4	**−25.3****	**−40.5****
	(1.4)	**(1.9)**	**(1.9)**
Caste dummy = 1 if Tibeto/Burman	−3.0	−22.8	−26.4
	(0.2)	(1.4)	(1.0)
Upland area	**39.9****	**47.8****	**87.6****
	(4.6)	**(5.2)**	**(5.9)**
Lowland area	**51.9****	−0.3	51.1*
	(2.1)	(0.03)	(1.7)
Bovine livestock	−2.4	−0.8	−3.2
	(1.3)	(0.5)	(1.0)
Altitude	−0.02	0.05*	0.03
	(0.8)	(1.7)	(0.7)
Percentage of literate adults	0.001	0.2*	0.2
	(0.01)	(1.8)	(0.8)
Male adults	9.9*	0.07	10.5
	(1.7)	(0.03)	(1.4)
Female adults	2.7	**8.7****	11.4
	(0.6)	**(2.0)**	(1.5)
Youths age 6–15	3.3	4.2	7.7
	(1.0)	(1.4)	(1.3)
Children under age 6	**−7.4****	−2.1	−9.5
	(2.2)	(0.3)	(1.2)
Seasonal dummy = 1 if	**47.4****	**35.2****	**82.8****
October–December	**(4.3)**	**(4.0)**	**(4.7)**
Constant	−28.5	**−73.2****	−102.6*
	(1.0)	**(2.1)**	(1.8)
Number of observations	167	167	167
Adjusted R-square	0.43	0.46	0.51

Notes: *significant at the 10 per cent level, **significant at the 5 per cent level. Absolute *t*-statistics in parentheses.

Random-effect demands for household agricultural labor, all four quarters (days/year)

	Male	*Female*	*Total*
Fuelwood shadow price	0.1	−0.2	−0.1
	(0.07)	(0.2)	(0.06)
Water shadow price	**4.3****	**1.9****	**6.5****
	(3.6)	**(2.3)**	**(3.6)**
Location dummy = 1 if Chhoprak	−7.2	−10.4	−17.5
	(0.6)	(1.3)	(1.1)
Caste dummy = 1 if Tibeto/Burman	**−7.4****	−17.7*	−26.5
	(0.5)	(1.7)	(1.3)
Upland area	**46.4****	**50.9****	**97.1****
	(6.3)	**(9.2)**	**(9.0)**
Lowland area	**37.7****	−2.0	**35.2****
	(4.0)	(0.2)	**(2.5)**
Bovine livestock	−0.8	0.4	−0.4
	(0.7)	(0.5)	(0.2)
Altitude	−0.01	**0.03****	0.02
	(0.6)	**(2.0)**	(0.6)
Percentage of literate adults	0.03	**0.2****	0.2
	(0.2)	**(2.0)**	(1.2)
Male adults	**7.8****	1.2	9.8*
	(2.2)	(0.4)	(1.8)
Female adults	4.5	5.9*	10.9*
	(1.0)	(1.7)	(1.6)
Youths age 6–15	1.3	**4.0****	5.5
	(0.4)	**(1.95)**	(1.3)
Children under age 6	**−8.4****	−4.5*	**−13.3****
	(2.6)	(1.9)	**(2.7)**
Seasonal dummy = 1 if April–June	**−40.6****	**−30.3****	**−71.2****
	(4.8)	**(5.3)**	**(5.5)**
Seasonal dummy = 1 if October–December	−0.2	−1.4	−1.5
	(0.02)	(0.2)	(0.2)
Seasonal dummy = 1 if January–February	**−35.6****	**−26.3****	**-62.1****
	(4.4)	**(4.7)**	**(5.0)**
Constant	10.35	−29.9*	−21.3
	(0.4)	(1.8)	(0.6)
Number of observations	451	454	451
Overall R-square	0.45	0.51	0.53

Notes: *significant at the 10 per cent level, **significant at the 5 per cent level.
Absolute *z*-statistics in parentheses.

Rainy season random-effect demands for household agricultural labor (days/quarter)

	Male	*Female*	*Total*
Fuelwood shadow price	−0.6	−0.7	−1.4
	(0.3)	(0.5)	(0.4)
Water shadow price	**4.8****	1.8	**6.6****
	(2.5)	(1.4)	**(2.3)**
Cut grass shadow price	−7.7	−12.8*	−20.8
	(0.6)	(1.68)	(1.2)
Location dummy = 1 if Chhoprak	−0.9	1.6	0.62
	(0.06)	(0.1)	(0.02)
Caste dummy = 1 if Tibeto/Burman	−13.4	−22.5*	−36.3
	(0.7)	(1.9)	(1.3)
Upland area	**49.3****	**54.7****	**104.2****
	(5.3)	**(8.7)**	**(7.5)**
Lowland area	31.3*	−10.1	21.0
	(2.6)	(1.2)	(1.2)
Bovine livestock	0.1	1.7	1.9
	(0.1)	(1.4)	(0.7)
Altitude	−0.01	**0.04****	0.03
	(0.2)	**(1.95)**	(0.7)
Percentage of literate adults	0.1	**0.2****	0.4
	(0.5)	**(2.3)**	(1.4)
Male adults	6.3	1.0	7.3
	(1.1)	(0.2)	(0.8)
Female adults	3.8	4.2	8.0
	(0.6)	(1.0)	(0.8)
Youths age 6–15	2.0	**5.0****	7.1
	(0.5)	**(2.1)**	(1.3)
Children under age 6	**−9.9****	**−6.3****	**−16.3****
	(2.3)	**(2.1)**	**(2.5)**
Seasonal dummy = 1 if July–September	**41.4****	**31.8****	**73.5****
	(4.1)	**(4.7)**	**(4.9)**
Constant	−35.2	**−61.2****	**−96.4****
	(1.1)	**(2.9)**	**(2.1)**
Number of observations	213	215	213
Overall R-square	0.45	0.56	0.55

Notes: *significant at the 10 per cent level, **significant at the 5 per cent level
Absolute *z*-statistics in parentheses.

Dry season random-effect demands for household agricultural labor (days/quarter)

	Male	*Female*	*Total*
Fuelwood shadow price	1.7	0.9	2.8
	(0.3)	(0.2)	(0.4)
Water shadow price	**8.0****	**4.1****	**12.2****
	(4.0)	**(3.0)**	**(4.1)**
Leaf fodder shadow price	−11.0	−4.4	−15.5
	(1.0)	(0.6)	(0.9)
Location dummy = 1 if Chhoprak	−15.4	**−25.3****	−40.5
	(0.8)	**(1.98)**	(1.4)
Caste dummy = 1 if Tibeto/Burman	−3.0	−22.8	−26.4
	(0.1)	(1.5)	(0.8)
Upland area	**39.9****	**47.8****	**87.6****
	(3.5)	**(6.2)**	**(5.3)**
Lowland area	**51.9****	−0.3	**51.1****
	(3.5)	(0.03)	**(2.4)**
Bovine livestock	−2.4	−0.8	−3.2
	(1.3)	(0.6)	(1.2)
Altitude	−0.02	**0.05****	0.03
	(0.5)	**(2.0)**	(0.6)
Percentage of literate adults	0.001	0.2	0.2
	(0.008)	(1.4)	(0.7)
Male adults	**9.9****	0.07	10.4
	(2.0)	(0.02)	(1.5)
Female adults	2.7	8.7*	11.4
	(0.4)	(1.9)	(1.1)
Youths age 6–15	3.3	4.2	7.7
	(0.7)	(1.3)	(1.1)
Children under age 6	−7.4	−2.1	−9.5
	(1.4)	(0.6)	(1.3)
Seasonal dummy = 1 if	**47.4****	**35.2****	**82.8****
October–December	**(4.0)**	**(4.3)**	**(4.7)**
Constant	−28.5	**−73.2****	−102.6*
	(0.7)	**(2.9)**	(1.9)
Number of observations	167	167	167
Adjusted R-square	0.49	0.51	0.55

Notes: *significant at the 10 per cent level, **significant at the 5 per cent level
Absolute *z*-statistics in parentheses